REMARKS

Claims 13-14, 16-19, 47-49 and 52-54 are currently pending. Claims 13, 47, 52 and 54 have been amended. Support for the amendments is detailed below. Claims 1-12, 15, 20-46, 50-51 and 55 have been cancelled without prejudice or disclaimer.

I. Applicants' Response to the Rejection under 35 U.S.C. § 112

Claims 13-14, 16-19 and 47-49 are rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement.

The Office maintains that the prior amendment of independent claims 13 and 47 introduces new matter with regard to the limitation of "brittle" solid particle. In response, it is submitted that the materials described at page 25, line 27 - page 26, line 3 all form a typical "brittle" ceramic material. In order to clarify this point, applicants have amended claims 13 and 47 based on the foregoing description of the specification. As such, non-brittle ceramic materials are not set forth by the claims. Wherefore, applicants respectfully submit that parent claims 13 and 47 as now presented, as well as claims depending therefrom, comply with the written description requirement.

In addition, each of parent claims 13 and 47, now recite the feature that generation of the aerosol of the fine solid particle material includes the step of heating a power of the fine solid particle material. Support for this feature is at least found at page 67, line 22; page 85, line 22; page 87, line 2; page 88, line 29; page 89, line 34, and throughout the specification.

By carrying out such a heating process to the fine solid particle material before the aerosol deposition process, the reactivity of the fine solid particle material is improved and densification of the deposited film is facilitated when the film is formed by the aerosol deposition process. In support of this position, applicants have attached a copy if an article by the inventor of the present invention published in 2004 (2004 Proceedings, 54th Electronic Components and Technology Conference, Volume 2, Issue 1-4, June 2004, Page 1614-1621

Vol 2), in which it is described that "(t)he morphology of the $BaTiO_3$ raw powder surface affects the dielectric properties of the AD film...", clearly indicating the advantageous effect of heating the power of the fine solid particle material before generation of the aerosol.

II. The Rejection under 35 U.S.C. 103(a)

Claims 50 and 51 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Renn (US 2003/0048314) in view of Hatono (US 7,175,921), all of record.

As noted above, claims 50 and 51 have been cancelled herein. Wherefore, applicants respectfully submit that the rejection is now moot.

Claims 52-55 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Renn taken with Hatono as applied to claims 50 and 51 above, and further in view of McMillan et al. (US 5,759,923 or record).

Applicants respectfully submit that the invention as now claimed is not obvious for at least the reasons that the combination of references does not teach all the features of the claims, nor is there any basis whereby a skilled artisan would derive the claimed invention based on the combination.

First, applicants have introduced the feature of heating the powder at the time of generation of the dry aerosol in each of independent claims 52-54. As noted above in regard to claims 13 and 47, this feature is found within the specification and affects the Aerosol Deposition (AD) process. None of the cited references teach or provide any reason to adopt this feature of the present invention.

Second, applicants respectfully note that the use of a lift-off process in combination

with a resist process as claimed is not well known in the art in relation to the claimed method. Specifically, the Office argues that, while McMillan, and also Renn and Hatono, are silent about the use of resist process, a lift-off process using a resist pattern is well known in the art.

However, a lift-off process used conventionally in combination with a resist process is an entirely different process over the AD process of the present invention, particularly in terms of the very large difference between the momentum of the particles that are impinged upon the substrate, and hence the resist film.

In the case of conventional CVD process or sputtering process, the species deposited upon the substrate or resist film are mere atoms or molecules, of which mass is far smaller than the fine solid particles of the present invention, which sprays the fine solid particles of, for example, the particle diameter of typically 10nm - 1μm as set forth in claim 17, upon the substrate with the speed of 200-400m/sec, together with a large amount of high speed carrier gas.

Applicants respectfully note that there is no basis in any of the cited references, nor elsewhere within the art at the time of the present invention, which provides for the AD process as set forth in Hatono et al. including the use of a resist process. A person skilled in the art would <u>not</u> have any reason to use a resist process in the AD process of Hatano as in the present invention, because of the different phenomenon ("impact activation") occurring at the time of the film deposition. The present invention demonstrates that a resist process is utilizable with the AD process. See paragraphs [0113] and [0137]-[0138] of the present invention. In short, the technology of AD process belongs to a different technical field distinct from the technical field of CVD or sputtering, in which conventional lift-off processes have been used successfully.

Wherefore, applicants respectfully submit that the combination of Ren, Hitano and McMillian does not result in the invention as now claimed, nor is there any basis for a skilled artisan to derive the claimed invention based on their combined teachings.

III. Conclusion

If this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. The fees for such an extension or any other fees that may be due with respect to this paper may be charged to Deposit Account No. 50-2866.

Respectfully submitted,

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Integrated RF Module Produced By Aerosol Deposition Method

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Abstract

Integrating and embedding various passive components like capacitors, and inductors, in one system module, is one of the attractive ways to achieve down-sizing, cost-reduction and higher performance in RF wireless communication products. Because the unique aerosol deposition (AD) method, we developed creates a dense ceramic film, that can be deposited at room temperature, and that possesses electric properties that are close to that of bulk ceramics, we can offer a module with passive components by incorporating different materials with various process temperatures.

In this paper, we have presented our novel approach to RF modules compared with other processes and methods. We also examined the microstructure and dielectric properties of high Q ceramic dielectric film for microwave filter applications and high K ceramic dielectrics deposited by the AD method at RT. As a result, a 500 dielectric constant and a 450 Q value at 10GHz were clearly attained with our ceramic AD films deposited on FR4 substrates at RT. Decoupling capacitors embedded in epoxy-based substrates fabricated as prototypes using AD film indicated about 300nF/cm^2.

By developing other various functional ceramic dielectric films with the AD method and increasing the dielectric properties of those films, we can expect to attain our target: a small RF integrated module incorporating a lot of functions.

I Introduction

Network systems combining information technology (IT) and communications have been growing very rapidly recently above 1 GHz as shown in Figure 1. The key technologies to build up the network systems are wireless communication, optical communication, the Intelligent Transportation System (ITS) and so on. For example, above 1 GHz, a lot of applications such as the cellular phone and Bluetooth are already in use and around 5 GHz, the Electric Toll System (ETC) and the wireless Local Area Network (LAN) have been commercialized as practical products. High speed wireless LAN applications in the quasi-milli-wave frequency and the car-mounted milli-wave radar have been studied intensively for practical uses. Optical communications have become popular and are also being researched for higher frequency systems for the future. [1].

In order to construct the network systems described above, the hardware technology in the microwave range, such as LSI technology, packaging technology, electric component technologies, etc. must be able to support them.

The requirements of the hardware are high-speed, wide-band transmission, miniaturization and multifunction capability. The latest cellular phones are equipped with a digital camera, GPS and Bluetooth and we can use Internet and E-mail as well as transmit a digital image easily. To meet these requirements, in the field of micro-electronic packaging and components, a small integrated RF module is definitely necessary. Lately, higher electric performance and smaller sizing is increasingly being demanded and the cost is considered an important factor as well [2, 3].

In this paper, to develop a low-cost RF module incorporating passive functions, we researched the current technology regarding the manufacturing method of wiring boards, summarized the requirements for the future module,

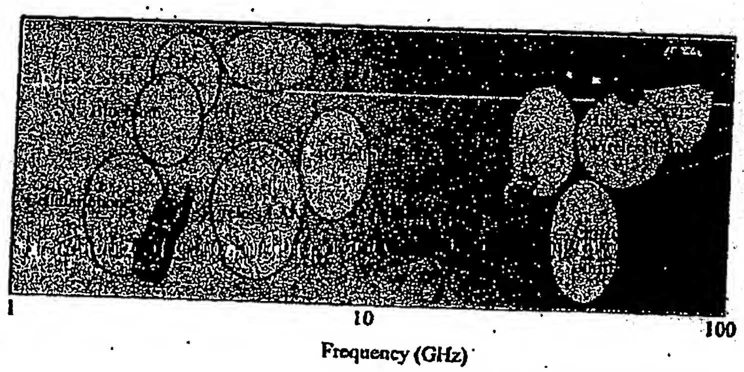

Figure 1 Various applications over 1 GHz in current and future network systems

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Table 1 Comparison of various current process technologies

Demand	Down-sizing Fine pattern	Integration	Cost	High frequency performance	Manufacturing process
Current properties	Finest wiring width (μm)	Capability for incorporating passive elements [Capacitance]		tan δ	
PWB	50	10-100 pF/cm2	low	high	Plating Laminating
Silicon technology (MCM-D)	5	100-1,000 nF/cm2	high	med.	Sputtering Photolithography
LTCC	50	10-100 nF/cm2	med.	low	Screen printing High temp. firing

and reveal the schematic images of the target. Furthermore, we establish that the key technology to actualizing the target module is the ceramic deposition method on resin substrate and that the aerosol deposition method we developed is a promising method. We present the scenario for obtaining the target module and in addition, in this paper we describe the recent R&D progress in the area of AD method.

II Current technology and development targets

As for the development of low-cost RF modules incorporating passive functions, the modules have been developed with three types of technology, as shown in Table 1.

In the printed wiring board technology, the multi-layer structure is constructed by laminating epoxy-resin film on FR4 substrate. Copper wiring is formed by plating, and the via holes between the epoxy layers are formed by laser radiation [4]. The minimum line width is 50μm with this method. When embedding and incorporating a capacitor, the epoxy/ceramic composite, in which small ceramic particles possessing a high dielectric constant are dispersed, is applied. Since the dielectric constant of the composite is limited, it is difficult to obtain a high dielectric constant. The Typical capacitance density is from 10 to 100pF/cm^2. Thus the cost for the materials and process is relatively inexpensive, and a low-cost substrate can be achieved. Epoxy resin with dielectric material used in this type of technology has a high dielectric loss. Therefore, this technology is not suitable for high-frequency applications.

With the MCM-D process originally used in silicon technology, a multi-layer thin film is constructed on a silicon wafer [5, 6]. In this process, sputtering is usually used for the conducting pattern, and polyimide resin is used for the interlayer dielectrics. Wiring of less than 10μm can be formed. The $BaSrTiO_3$ dielectric film, having a dielectric constant of about 400 and a thickness of about 300nm is applied by sol-gel or sputtering, as capacitor material.

However, because annealing with oxygen in the atmosphere is required to increase the dielectric constant, it is difficult to apply this dielectric film for a copper wiring system. If this problem is overcome, about 500 nF/cm^2 of capacitance density can be achieved because a thin film can be formed. However, the cost is higher than that of other technologies because the photolithography is usually carried out using a vacuum system equipped in a clean room. The polyimide resin has a relatively lower dielectric loss compared to other resins and these properties should be improved upon, since they are higher than those of ceramics.

LTCC is obtained by printing a thick film wiring pattern on green-sheet by screen printing, laminating the green-sheets printed and co-firing them around 1000°C. The minimum line width is around 50μm, because of the screen printing method [7]. For the material for the incorporated capacitor, a composite consisting of ceramic, with a high dielectric constant, and glass is applied. This material is cast in the sheet configuration and is constructed with a multi-layer structure and thus achieving approximately a 50nF/cm^2 capacitance. Because this technology includes the high temperature firing process, cost reduction is limited. Yet, the manufacturing cost is lower than that of the module manufactured with silicon technology. Ceramics are suitable for microwave applications, because the high frequency characteristics of ceramics are superior to that of resins.

As can be seen from Table 1, LTCC is the most promising candidate for the RF module among all current technologies. However, the LTCC does not satisfy all of the requirements of the RF module, although all of the requirements must be met in the future. To meet these requirements, the following four factors for the materials and processing must be satisfied simultaneously.

(1) adaptation of the photolithography process in view of down-sizing and creating a fine pattern
(2) use of low-cost resin-based FR4 as a substrate
(3) adaptation of a low-cost plating method for pattern wiring
(4) introduction of ceramics with superior dielectric characteristics at high frequencies

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Figure 2 depicts the RF module incorporating the above four requirements. The process of forming a multi-layer structure and the Cu plating process is the same as that of current build-up substrate processes with epoxy-resin on FR4 substrates.

Therefore, the key development towards the actualization of the above RF module is considered to be the ceramic deposition technology on a resin substrate such as FR4. The following three factors are required for that ceramic deposition.

(1) it must be deposited at a temperature lower than the endurance temperature of the resin (about 250°C in the case of epoxy)

(2) it must have superior dielectric properties (ex. higher dielectric constant of more than 1,000; a low dielectric loss) close to bulk material

(3) it must deposit a thick film which adapts to the surface roughness of a build-up substrate

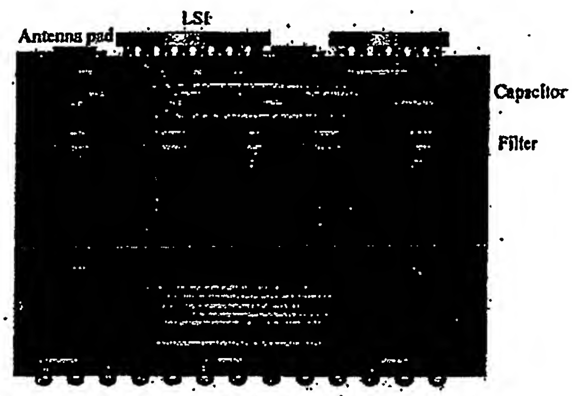

Figure 2 Schematic images of a future RF module

III Ceramic film deposition technology

Table 2 lists the characteristics of various ceramic film depositions corresponding to the three requirements described above. The ceramic film deposition by sputtering on a resin substrate is difficult because post annealing at a minimum of 300°C is required. However, a dielectric constant around 500 can be achieved after the post-annealing at about 600°C. Nevertheless, obtaining micron-level thicknesses is difficult with sputtering [8].

Post-annealing above 300°C is also required with the sol-gel method and hence it is difficult to make a deposition on a resin substrate. The dielectric constant obtained is lower than that with sputtering and the maximum value attained is approximately 400. A thickness of about 5μm can be obtained with the multi-coat process [9].

Using the thick film method, a ceramic film can be produced by firing thick film with the screen printing method at around 1000°C. Although a film having the dielectric properties close to that of bulk can be obtained, it cannot be applied to a resin substrate because of higher processing temperatures.

A ceramic/polymer composite film can be obtained by curing the film, consisting of ceramic particles with a high dielectric constant such as $BaTiO_3$ and epoxy polymer, coated on the substrate at around 200°C. In this process, the process-temperature and film-thickness requirements are met, but a high dielectric constant cannot be attained. The research group at Georgia Institute of Technology optimized the surface treatment of ceramic particles, the particle size of ceramics and the composition of resin suspension. As a result, they reported that a dielectric constant of about 150 can be obtained by introducing the mixed powder of $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (dielectric constant: about 15,000) and $BaTiO_3$ (dielectric constant: about 3,000) by 85 vol% in the epoxy-resin (dielectric constant: 3.2) matrix [10]. The maximum dielectric constant is considered to be about 150 in this composite film coating process.

Table 2 Comparison of various ceramic film deposition

Demand	Low process temperature	High dielectric constant	Thick film
	~200°C	1,000~	1~10μm
Sputtering	△ (300°C~)	△ (about 500°C)	×
Sol-gel method	△ (300°C~)	×	△(~5μm)
Thick film method	×	O	△(5μm~)
Ceramic/polymer composite film	O	×	△(5μm~)
Aerosol deposition method	O	O	O

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In contrast, the aerosol deposition method can satisfies the above three requirements.

IV Aerosol deposition (AD) method

The AD method is the groundbreaking deposition technology developed by one of the authors of this paper: Dr. Akedo at the National Institute of Advanced Industrial Science and Technology (AIST). Using this AD method, dense ceramic film can be deposited at room temperature [11, 12].

Figure 3 shows the equipment for the AD method. With this method, the film is formed by bombarding the aerosol ceramics generated in the vibration unit, which is transferred through a tube and ejected from the nozzle located in the chamber that is vacuum pressurized. The ceramic particles, having a powder diameter from 0.05 to 2μm, are accelerated to a speed of 100 to 1,000 m/sec., and the ceramic film is deposited on a substrate at room temperature, with the deposition rate ranging from 10 to 30μm/min. Because the temperature does not rise even in the area neighboring the deposition location on the substrate, deposition to the surface of the resin material is possible. The raw ceramic powder is not decomposed on the molecular level during the deposition process. Therefore, a composition change does not occur even in the complex compound. Since the ceramic raw powder is used as a starting material, it can control the complicated composition and the electrical properties that are close to that of bulk ceramics. To date, only the deposition of PZT piezoelectric film and alumina film has been reported.

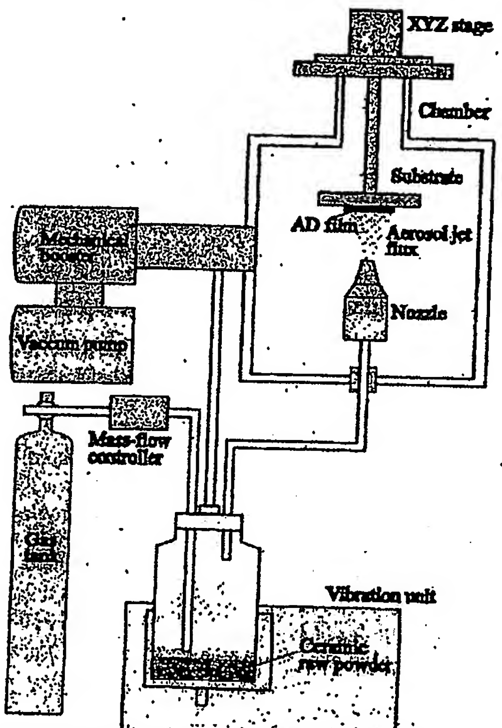

Figure 3 Schematics of the equipment for aerosol deposition

The potential of the AD method depends on the composition of the ceramics and the characteristics of the raw powder in particular. At present, not enough about the mechanism of deposition is understood. Some ceramics cannot be deposited, and all of the ceramics even in the same composition are not deposited with the AD method.

V Experimental procedure

The raw powders used in this study are Al_2O_3 coated TiO_2 powder (average particle size: 0.3μm) shown in Fig. 4, $Ba(Zn_{1/3}Ta_{2/3})O_3$ (average particle size: 0.5μm) produced by the solid state reaction method as a filter application, and $BaTiO_3$ (average particle size: 1.0μm) as a capacitor application. From SEM observations, these three raw powders have almost spherical shapes.

The aerosol deposition was carried out using the equipment shown in Fig. 3, under the following conditions (Deposition time: 10 min., Gas pressure: 2 kg/cm^2, Gas flow: 4 l/min., Base pressure in chamber < 10 Pa). The carrier gases used in this study were O_2, N_2 and He. The deposition rate was almost 1μm/min. After depositing the AD film, the microstructure of the film was observed using a Scanning Electron Microscope (SEM) and a Transmission Electron Microscope (TEM). The dielectric constant and dielectric loss at 10 GHz was measured using the ring resonance method, and those at 10 kHz were measured using the capacitance-bridge method.

Figure 4 Al2O3 coated TiO2 powder used in this study

VI Results and discussions

(1) Deposition mechanism

In order to understand the mechanism of depositing an AD film, the microstructure of the AD film was examined with a SEM and TEM. Figures 5 (a) and (b) show the surface view and the cross-sectional view of the microstructure of the TiO_2/Al_2O_3 AD film deposited in N_2. In Fig. 5 (a) (Top view), round shape particles of around 30 nm are observed. By contrast, a lamellar structure with the TiO_2/Al_2O_3 is observed in the cross-sectional view. Since the raw powder is spherically shaped, it is thought that the ceramic particles are collapsed and are adhered to the substrate. It seems that the lamellar structure is formed by the plastic deformation of the collapsed particles that are piled and stacked as shown in Fig. 6. Furthermore, from the fact that the grain size of the film is about 10 times smaller than the particle size of the raw

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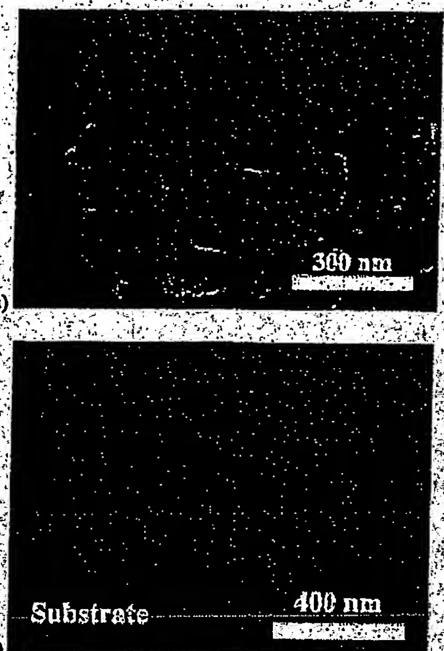
material powder, it is thought that of all of the powder only small-size particles around 50 nm in diameter are flown in the aerosol and deposited on the substrate. Since this film is very dense, it is not damaged even after scratching the film with a needle.



(a)

(b)

Figure 5 Microstructure of a Al2O3/TiO2 AD film deposited in N2 (a) (Top view), (b) (Cross-sectional view)

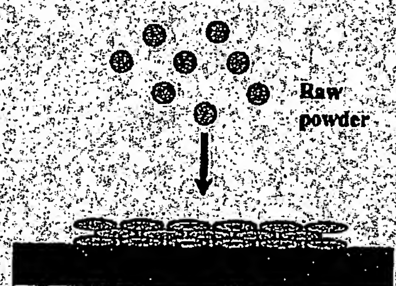


Figure 6 Schematics of the mechanism model of AD deposition

(2) Filter material

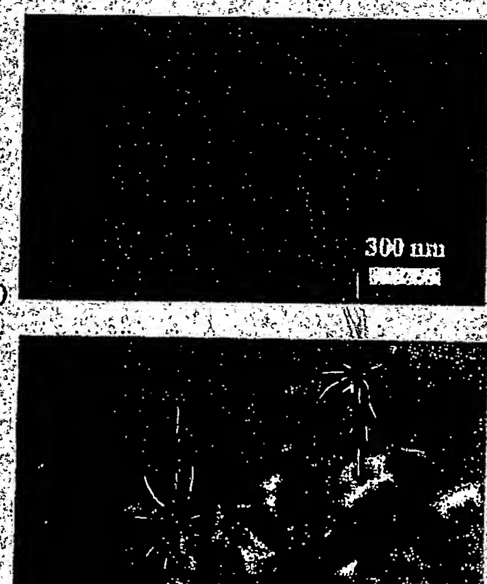
Figure 7(a) and (b) show the microstructure of a $Ba(Zn_{1/3}Ta_{2/3})O_3$ AD film deposited in O_2 and He atmosphere, respectively. In the AD film deposited in O_2 (Fig. 7 (a)), large pores are not observed and a dense lamellar structure is formed having the same morphology of Fig.5. In contrast, large pores and large particles of more than 200 nm are observed in the film deposited in He (Fig. 7 (b)). The small particles less than 50 nm, are located between the large particles. It seems that the small particles act as a bonding agent between the large particles, as shown in Fig. 8. Table 3 lists the speed of sound of gases at room temperature. The speed of sound of He is more than twice as much as that of other gases such as N_2 and O_2. It is thought that the He gas carries much larger particles, because of the high speed of sound. It seems that these large particles prevent the homogenous lamellar structure, and introduce large pores into the AD film.

With the high purity gases used in this study, some of the oxygen became a contaminant. As shown in Table 3, three ppm of oxygen is in the He, and 50 ppm of oxygen is in the supplied N_2. Table 3 shows the relationship between the carrier gas for deposition and the dielectric properties of the $Ba(Zn_{1/3}Ta_{2/3})O_3$ film deposited.

Table 3 Speed of sound of gas at RT and the dielectric properties of a $Ba(Zn_{1/3}Ta_{2/3})O_3$ AD film deposited in various carrier gases

Carrier gas	O_2 content (ppm)	Speed of sound (m/sec)	Dielectric constant [10GHz]	Q value (1/tan δ) [10GHz]	Film color
He	3	965	70	94	Dark grey
N_2	50	353	52	220	Grey
O_2	—	330	45	450	White grey

*Bulk $Ba(Zn_{1/3}Ta_{2/3})O_3$: 30 (Dielectric constant), 5,000 (Q value)



(a)

(b)

Figure 7 Microstructure of Ba(Zn1/3Ta2/3)O3 AD film deposired in O2 (a), in He (b)

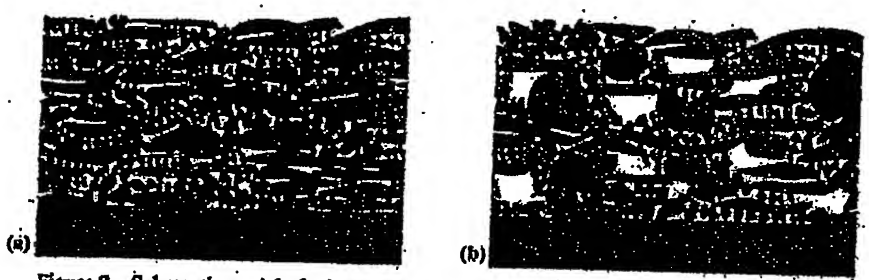


Figure 8 Schematic model of microstructure of AD film (a) O_2 deposition, (b) He deposition

From these results, it seems that the dielectric properties are dependent on the oxygen content in the carrier gas. The dielectric constant is decreased by increasing the oxygen content. In contrast, the Q value is increased by increasing the oxygen content. When conventional oxide ceramics are fired at low-oxygen partial pressure, oxygen point defects are formed by reduction, depending on the enthalpy of the defect formation, the band gap Eg, the mobility of electrons and so on.

$$O_o \rightarrow 1/2\, V_o^{\cdot\cdot} + e^-$$

When oxygen defects are introduced in dielectrics, the surface color changes from white to black and properties similar to n-type semiconductors are seen. It is known that a high dielectric constant and a low Q value are obtained when fired in low oxygen partial pressure. As a result, it is thought that a similar phenomenon to that of bulk ceramics fired in low oxygen partial pressure takes place in this aerosol deposition. Compared with the dielectric properties of bulk $Ba(Zn_{1/3}Ta_{2/3})O_3$, the dielectric constant of $Ba(Zn_{1/3}Ta_{2/3})O_3$ AD film is higher. Therefore, it is thought that some of the semiconductor layer is still formed in a $Ba(Zn_{1/3}Ta_{2/3})O_3$ AD film. Further study should be conducted to better understand these experimental results.

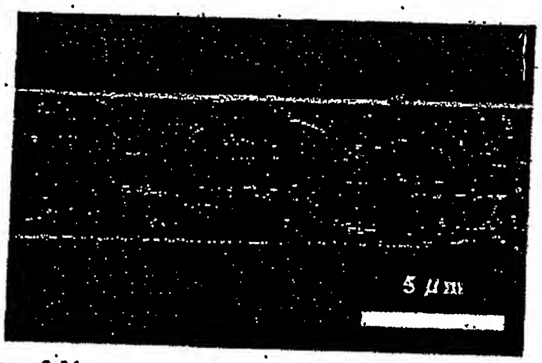


Figure 9 Macro-structure of a BaTiO3 AD film on epoxy resin substrate

(3) Capacitor application

Figure 9 shows the macro-structure of a $BaTiO_3$ AD film on an epoxy resin substrate. By optimizing the powder characteristics, it is evident that a dense $BaTiO_3$ AD film can be obtained. The morphology of the $BaTiO_3$ raw powder surface affects the dielectric properties of the AD film. In the case of the deposition using as-received $BaTiO_3$, the dielectric constant of the film is about 100 @ 10kHz measured by the capacitance bridge method as shown in Table 4. In contrast, when powder calcined at 900°C for 1 hour to modify the morphology of the powder surface is used, the dielectric constant is increased to 400, which is the highest dielectric constant of all dielectric film deposited at room temperature.

The surface energy of the powder is decreased when heat treated at a high temperature, and thus promotes the reactivity of the powder. It is thought that a strong bond between particles in an AD film is formed, and that a dense film can be obtained by using the heat-treated powder. As a result, the high density of the film seems to increase its dielectric constant.

Table 4 Dielectric properties of $BaTiO_3$ AD film

$BaTiO_3$	Dielectric constant [@10 kHz]	tan δ (%) [@10 kHz]
as-received powder	100	0.01
calcined powder (900℃, 1h)	400	0.02

*Bulk $BaTiO_3$: 3,000 (Dielectric constant), 0.01 (tan δ)

VII Feasibility study of RF module

Theoretically, the target RF module shown in Fig.2 can be developed, because the ceramic film is deposited at room temperature using the AD method. To verify this concept experimentally, we manufactured a prototype for the target RF module. The prototype is a three-layer ceramic capacitor formed on a FR4 substrate by using the AD method, photolithography, and Cu plating. Figure 10 shows the simple manufacturing process for this prototype of a multilayer capacitor on FR4.

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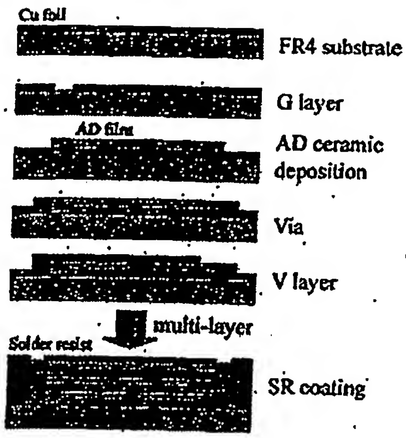

Figure 10 The Manufacturing process for a prototype of a multilayer capacitor on FR4

First, a single-sided copper clad laminate FR4 is prepared, and the photo-resist is coated on the substrate. After the resist is exposed and developed, Cu is etched and a Cu ground pattern is formed. Next, the AD film is deposited. The AD film is etched after the resist coated on the AD film is exposed and developed. After this, a blanket Cr/Cu sputter film is deposited, and a Cu plate is formed. The photo-resist is coated on the Cr/Cu/Cu layer, exposed and developed, and unnecessary parts are etched. This process is repeated three times. Finally, the prototype is completed after the solder resist is coated, exposed, and developed.

Figures 11 and 12 show the cross-sectional view and the appearance, respectively, of the multilayer capacitor manufactured by AD method as a prototype. Dense three-layered AD film on FR4 can be observed in Fig.12. Capacitance measurements indicate this capacitor as having 300nF/cm2. Higher capacitance densities can be attained easily by improving the process technology, since this prototype is solely to verify the manufacturing process.

Figure 11 Cross-sectional view of a multilayer capacitor produced by the AD method

This trial fabrication of this prototype establishes that the AD method and Cu plating process enables the incorporation of multi-layer ceramic capacitors on FR4. Therefore, integrating various passive functions into a PWB is made feasible by developing various ceramic AD films in the future.

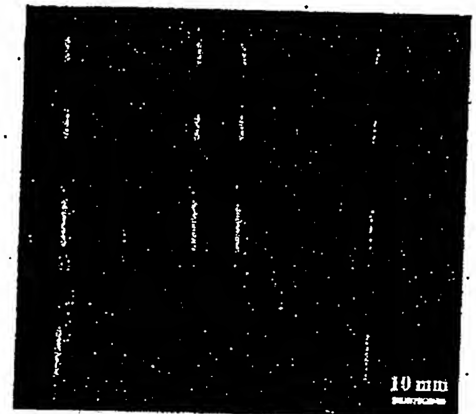

Figure 12 Part of a multilayer capacitor on a FR4 manufactured as a prototype

Conclusions

In order to obtain a low-cost RF module incorporating passive functions for the next generation, we researched the current technologies for wiring board manufacturing methods and ceramic deposition methods. Furthermore, we examined the possibility of a unique AD method we developed for the experimental target RF module. The conclusion is as follows:

(1) The AD method is a promising key technology for future low-cost RF module incorporating passive functions, since dense ceramic film can be formed at room temperature on FR4.
(2) The AD method can produce more superior dielectric properties (ex. dielectric constant, tan δ) in comparison with other methods, such as sputtering, so-gel, ceramic/polymer composite etc.
(3) The dielectric properties of AD film are affected by the speed of sound of the deposition gas, oxygen pressure of the deposition gas, the surface morphology of the ceramic powder and other factors.
(4) By applying the AD method and Cu plating process, it is evident that a multi-layer ceramic capacitor with high capacitance density on FR4 can be obtained.
(5) The dielectric constant and the Q value of ceramic film produced by using the AD method can be increased further by optimizing the raw materials and the deposition conditions. By using a larger variety of ceramic materials, various RF integration modules with multiple functions can be produced.

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